A 2.3-GHz Maser at Usuda, Japan, for TDRSS-Orbiting VLBI Experiment

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A 2.3-GHz traveling-wave maser/closed-cycle refrigerator (TWM/CCR) that is used in the DSN was installed and successfully operated on the 64-m antenna at Usuda, Japan. The TWM/CCR supported the first very long baseline interferometry (VLBI) experiment to use an orbiting spacecraft as one of the receiving antennas. The experiment required a 15-K receiving system over a 2271- to 2285-MHz bandwidth. The maser installation was made during June 1986, and successful VLBI measurements were made during July and August 1986 and again in January 1987.

I. Introduction

A request was made to the Radio Frequency and Microwave Subsystems Section at JPL to install and operate a traveling-wave maser/closed-cycle refrigerator (TWM/CCR) on the 64-meter antenna at the Usuda Deep Space Center (UDSC) near Usuda, Japan. The 15-K receiving system was required for the conceptual demonstration of a very long baseline interferometry (VLBI) experiment that uses an orbiting receiving station at one end of the baseline [1], [2]. The TWM/CCR was previously used at Usuda for the tracking of the International Cometary Explorer (ICE) during the comet flyby period in 1985. This previous maser system installation has been thoroughly described in [3], so a detailed description will not be repeated here. Although the maser system was similar to the first implementation, modifications were made to improve its operation and reliability.

II. TWM/CCR

The TWM/CCR was originally built and implemented in the DSN in 1973 and was one of the first 2.3-GHz masers to use the cold probe type of low-noise cryogenically cooled input transmission line [4]. Due to the age of the system and the amount of shipping and handling to which it had been exposed, it was felt necessary to open the CCR and make the desired corrections and improvements.

The signal input impedance match had degraded considerably in relation to its original performance. The input return loss was increased to 13 dB at 2270 MHz and 17.5 dB at 2300 MHz, a 3- to 4-dB improvement, by replacing and tuning a short section of coax in which there had been a slight migration of the Teflon dielectric. No changes were made to the maser structure itself.

The shock and vibration that had occurred during previous shipping had caused some hardware to become loose. Most notable were the screws that attach the thermal switch. A loose connection at this point causes a poor thermal contact and results in a longer maser cool-down period. The problem was attributed to rotational loads that could be applied to the joint during shipping, coupled with the soft copper material involved. An additional structural brace made of thin-wall stainless steel tubing has been installed on two masers to date, and the problem has not recurred in the last 2 years.

New cryogenic temperature sensors were installed on the refrigerator, and the CCR controller in the instrumentation rack was modified to provide digital readout capability for the sensors. These sensors provide a continuous, accurate readout of refrigerator temperatures, enabling more accurate diagnosis of refrigerator performance problems than was previously possible. Identical sensors are now being installed in DSN maser systems.

III. Shipping, Installation, and Operation

The experience gained during the shipment of the TWM/CCR to Japan in 1985 helped prevent many of the problems that can occur due to the complexities of foreign customs policies. With this information available, it was possible to predict and eliminate all of the previous delays, and the system arrived in Usuda 8 days after its shipment from Los Angeles International Airport.

The beam-waveguide feed configuration of the Usuda antenna greatly contributed to the ease of installation of the TWM/CCR. Since most of the mounting hardware had been left in place in the laboratory environment of the beam-waveguide antenna, minimal problems or delays were encountered during installation. Whereas installation in a DSN Cassegrainian antenna requires advance scheduling of an 8-hour maintenance period, installation of the TWM/CCR system was completed and the cryogenics were ready to start one day after its arrival, with no interruption of ongoing tracking activities or maintenance.

The initial operation of the system was not without problems. One compressor and a CCR drive unit were replaced during the first week. After that, the maser continued to be operational without further mishaps during the 1-month-long TDRSS experiment 1986 observing schedule. In January 1987, during the second phase of the experiment, the TWM/CCR was easily restarted and operated without difficulty during the 10-day 1987 observing schedule.

The maser was tuned to 2277 MHz, and the initial system gain and power levels were adjusted. System temperature measurements were first made on July 3, 1986. The gain was adjusted to 50 dB with a bandwidth of approximately 20 MHz at the –3 dB points. Using the cold sky/ambient load Y-factor method, the system noise temperature was measured to be 14.9 K at an antenna elevation of 90 degrees. During January 1987, the maser gain was adjusted to 48 dB at a bandwidth of approximately 25 MHz. The system temperature was measured to be 15 K. This performance was essentially identical to data taken in 1985 for the ICE installation, when system noise temperature measured 15 K at 2270 and 2295 MHz.

IV. Conclusion

For the second time in as many years, a complete TWM/CCR system was shipped and installed on a foreign antenna in a timely manner. The project was a relatively cost-effective one, since it largely involved preexisting hardware. The TWM/CCR system performed reliably without the benefit of an operational spare and contributed to the success of the VLBI experiment it supported. The beam-waveguide feed configuration of the Usuda 64-m antenna, in contrast to the DSN Cassegrainian antennas, also contributed to ease of installation and operation.

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References

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